Appendix 5 – Safety on the Fehmarnbelt Bridge

This brief concerns two themes related to safety on a Fehmarnbelt bridge.

Firstly, the general safety concept underlying the design of a Fehmarnbelt bridge will be explained. This will then be elaborated on in relation to the four main types of events on a bridge which involve safety risks: ship collision, traffic accidents, fire and terrorism.

This brief does not deal with details of the structure of the emergency preparedness for a future Fehmarnbelt Link, since this must be determined based on close dialogue with all relevant authorities on the Danish and German sides of the link. The dialogue with the emergency management authorities has its starting point in an account of the legal basis for Danish and German authorities' safety and emergency work, which Femern A/S has prepared, with a view to determining the organisational frameworks for a Danish-German emergency cooperation on the fixed link as well as the proposed safety concept which has been drawn up as part of the preparation of the bridge's technical design. The discussions with the emergency management authorities in Denmark and Germany commenced in November 2010 and the intention is partly to determine the organisational frameworks in the course of the next 6-9 months, partly to obtain the emergency management authorities' views regarding the technical aspects of the safety concept for both bridge and tunnel.

General safety concept
The overall objective for the Fehmarnbelt Bridge is that the bridge must be at least as safe as a motorway or railway line of the same length in the open landscape.

In order to ensure this, the planning of the Fehmarnbelt Bridge and its installations is based on an overall safety concept with the following prioritisations:

- *Accidents must be prevented*
  The primary goal is to achieve a design which prevents accidents and other emergency situations.

- *The consequence of accidents and emergency situations must be minimised*
  The secondary goal is to minimise the consequences of accidents and emergency situations if they cannot be averted.

- *The bridge design must support the emergency work*
  The third goal is to provide sufficient safety systems and emergency preparedness procedures in order to ensure that the rescue services can handle accidents and emergency situations with a high degree of safety.

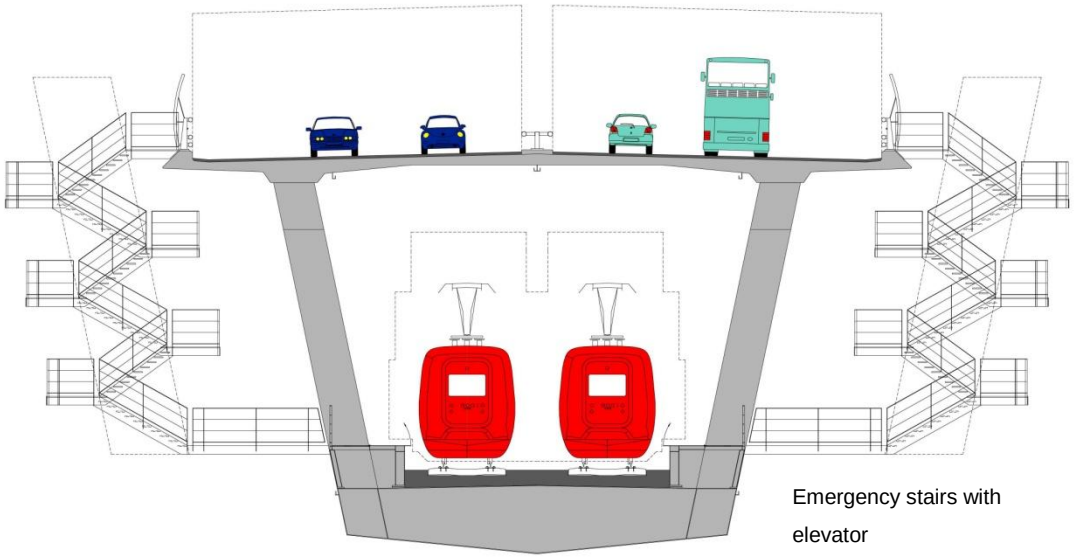
The following describes the most important measures that have been decided on for each of the three priorities.

Prevention of accidents
In order to prevent accidents, a number of initiatives will be implemented. To begin with, the road and rail traffic is separated so the part that is not affected by an accident can be used by rescue personnel. The motorway has full emergency lanes, which means that the risk of having to cordon off a traffic lane in the event of minor accidents is significantly reduced.

The biggest risk of a serious accident on the bridge is ship collision with a bridge pier or a bridge span. Therefore, a VTS system (Vessel Traffic Service) will be established similar to the Great Belt and Øresund, which means a significant reduction of the risk of dangerous situations arising with vessels.

Major maintenance work, such as replacing the wearing course on the motorway, will be carried out with the least possible inconvenience to traffic given that drive-through openings per 5 km will be established similar to the situation on land, which is why the traffic will only need to be diverted over a 5 km stretch. This is a far safer method than replacing a wearing course on a traffic lane while the traffic passes close by in the other traffic lane.

Figure 1: Cross-section of the Fehmarnbelt Bridge



Minimising consequences of accidents
The two halves of the motorway are separated by a centre crash barrier so in the event of an accident in the one direction, the bridge will be closed to normal traffic and rescue vehicles can quickly reach the site in the unaffected carriageway. A small drive-through opening will be established for an ambulance at each kilometre so it can quickly go to and from the accident site. An even faster option is for a helicopter to land and leave on the cordoned off traffic lane (however, not on an main bridge due to its cable stays).

The bridge design must support the emergency preparedness work
In the event of an accident in a passenger train, uninjured passengers can move along the train for a distance of, at the most, 400 m to a stairwell which leads up to the motorway so they can be collected by buses. Rescue personnel have the possibility of transporting injured people to the road deck along the emergency sidewalk to elevators with room for one stretcher. There are elevators in connection with the emergency stairs, which means every 400 m.

In the event of fire in a train, emergency responses will take place on the motorway and fire extinguishing will be carried out by connecting hoses on the railway deck at the access stairs. The hoses are supplied from fire engines on the motorway via permanent pipes between the two decks.

Detailed plans for fire fighting and rescue work for various accident scenarios will be prepared and the most important will be tested in practical drills before the opening of the Fehmarnbelt Bridge.

On the basis of the conceptual bridge design, risk analyses have been conducted which estimate how often accidents will occur with fatal outcomes on a bridge. The results show that the risk of fatal accidents on a Fehmarnbelt bridge is lower than on ordinary motorway and railway stretches of the same length.

Safety problems

The most significant safety problems in regard to a bridge link will be ship collision, traffic accidents, fire and terrorist attack.

Collision
The three pylons of the main bridge are most exposed to collision. Their foundations are designed so there is the greatest possible chance that a ship on a collision course will slide off the rounded surfaces. Moreover, the pylons are of such tremendous weight that their technical function is not affected by a direct collision of even very large vessels of up to at least 250,000 DWT.

The four bridge piers closest to the pylons (two on each side) are similarly protected by rounded concrete shells, which provide the same possibility that the majority of possible collisions will be grazed collisions. Since the risk of collision with these is significantly smaller than for the pylons, they are not dimensioned for the worst case scenario in vessel collision, but rather for collision with a vessel of 120,000 DWT. The remaining bridge piers are dimensioned for collision with vessels of 20,000 or 10,000 DWT, depending on the distance from the shipping route.

Collision with the Fehmarnbelt Bridge's superstructure (bridge girders) would be a very unusual event, since only in the inshore regions is the bridge so low that standard vessels could collide with it. Therefore, the superstructure is dimensioned for a somewhat lower collision force than the bridge piers.

In the worst case scenario, where a vessel is on a collision course towards the bridge and does not react to the VTS system's warnings, there would be sufficient time to close the bridge so human life is not lost in the event of a collision.

In the design of the Great Belt Bridge and Øresund Bridge a calculated disruption of the connection due to an accident (essentially vessel impact) was accepted of, on average, 1.3 days per year. The Fehmarnbelt Bridge is designed more conservatively, which means that the disruption risk is down to 0.7 days per year.

Traffic accidents

Traffic accidents on a motorway occur most frequently in connection with approach and ramp areas because vehicles brake suddenly to enter an off-ramp or vehicles drive onto the motorway at slow speed. People and animals crossing the motorway also cause accidents. These types of accidents will not occur on the Fehmarnbelt Bridge, which is the most significant reason why accidents on the bridge will be less common than on a motorway on land.

Something similar applies to the railway line given that switch tracks are not planned to be established on the bridge. A possible derailing of a train on the bridge would, with great probability, be intercepted by the derailing barrier which is located under the emergency sidewalk. Despite this, the bridge superstructure will be dimensioned so that collapse does not occur if a derailed train collides with the bridge's steel construction.

Fire

As a basis, burning vehicles on the bridge are not more hazardous than on motorways on land. However, the worst imaginable fire in a tank truck on the cable-stayed bridge could destroy one of the bridge's cables, but this situation is covered in the design: The bridge will not sustain any permanent damage and the traffic can be maintained to a considerable

extent until a new cable is fitted. A serious fire in a train can destroy the bridge's steel construction to a considerable extent without this leading to collapse. Thus, the conditions are as safe as they are on land.

Terrorist attack

The assessment does not include the Fehmarnbelt Bridge being an obvious target for terrorists. The Fehmarnbelt Bridge is located in a sparsely populated area, traffic density is relatively low compared to the traffic in and around the larger towns and it is assessed, however, as being difficult to carry out a terrorist attack against Fehmarnbelt Bridge in a way that leads to major loss of life and/or major material damage to the bridge. Among other things, this is connected to the fact that the blast pressure from a bomb explosion will spread into the open air which will limit the damage to the Fehmarnbelt Bridge.